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Topological Design of Computer Communication Network Structures: A Comprehensive Review

B. Nethravathi[1*], V. N. Kamalesh[2] and V. G. Manjunatha Guru[3]

[1]Department of ISE, JSSATE, Uttarahalli-Kengeri Road – 560060,Bangalore, Karnataka, India; nethravathi.sai@gmail.com
[2]Department of Science and Engg., TJIT, Bannerghatta Main Rd, Gottigere – 560083, Bangalore, Karnataka, India; kamalesh.v.n@gmail.com
[3]Shree Vedantha PU College, Subramanyapura - 560062, Bangalore, Karnataka, India; vgmanjunathji@gmail.com

Abstract

Background: One of the key considerations in the topological design of a network is the fault tolerance and survivability of the network topology. A deterministic measure for fault tolerance proposed by computer scientist and researchers is the k-node connectivity number of the network graph. Fault may happen at the physical level or at the software level. **Method:** A few heuristics and methods are proposed in the literature for the design of k-node connected network topological structures. The methods are analyzed on the parameters such as link optimality, computational efforts, repeated searching of nodes, adopting node numbering techniques, mathematical modelling, generality of the methods etc. **Findings:** This article portrays the comprehensive study and investigation of existing works and current developments on the design of k-node connected topological design of computer communication network structures, applicable for both wired and wireless network structures. This paper also highlights on the various design methods applicable for specific cases and also compares the existing and current methods, for the design parameters considered. **Applications/Improvement:** The study concludes by stating that the previous methods and strategies are restricted only to a few network design parameters. However there is no single method which addresses most of the issues, hence there is a scope for future exploration design methods.

Keywords: Computer Networks, Network Topology, Optimal Networks, Topological Design, Fault Tolerance, K-connected

1. Introduction

Wide range of the computer communication network application systems such as wireless cellular telephonic talk or applications like credit card transfer or public switch network, Internet etc., demands the availability of reliable networks systems. The network systems[1] are reliable if the underlined physical system is fault tolerant. Fault in any large scale or a medium scale or parallel processing real time network system may be due to hardware failures such as faulty components or communication line failure etc. Further the fault may also occur due to the reasons of software errors.

The hardware[2] faults can be mathematically analysed by creating mathematical models. To design a reliable network it is extremely important to understand the network performance under various conditions. The networks are complex systems, by combining computational sciences and network survivability theory significantly improves the capability of analysing and designing various forms of computer communication network topological structures.

The researcher[3,4] and communication engineers have considered the k-node connectivity of the communication network as the deterministic graph theoretical measures for the fault tolerance. With the major objective to achieve end to end performance and network ready time for usage without interference.

* *Author for correspondence*

Routing[5] in a wireless sensor network generally depends on the changing network topological structure. Future generation wireless systems[6] that are capable of communicating through heterogeneous technology such as Wi-Fi, WiMax, UTMS mobile and navigation applications developed on web 2.0 demands the design of fault tolerance survivable network.

2. Exploration of the Resource Materials, Existing Heuristics and Methods

Due to the importance of problem, few heuristics and methods for designing k-node connected topological structures have been proposed by network design engineers, based on specific assumption. This section discusses the existing methods and techniques in detail.

One of the oldest heuristic method for producing k-connected computer network topology is given[7]as link deficit algorithm. In this method the nodes are selected for adding the link based on the following criteria

- Highest deficiency given priority
- If the deficiency is same choose the nearest neighbour.

Till the confined network is produced.

Latha and Srivatsa[8], have given a strategy in their article, "on the topological design of communication network for the generation of k connected wireless network". In this method 2k number of nodes are randomly positioned. To start with, the randomly positioned nodes are numbered by decimal numbers. Subsequently the randomly placed node numbers are transformed to its corresponding grey code (k-bit). A link is established between two different nodes, if they differ only in one place. Thus establishing the k-connected network.

Latha and Srivatsa[9], have proposed algorithm for the design of cheapest survivable k connected networks with n nodes by considering 3 different cases:- where k is even connectivity and n is even or odd, k is odd connectivity and n is even, where k and n are both odd. In the case of even or odd number of nodes with even connectivity the nodes are connected to k/2 nodes in both the directions. In case of even number of nodes and odd connectivity number the nodes are connected to the (k-1)/2 nodes both clock wise and anticlockwise directions to get (k-1)-connected network. Further the same network is extended to get the k-connected network by adding the link which connects diametrically opposite nodes. In the case of odd connectivity number and odd number of nodes the network the network with n nodes and (k-1)-connectivity is generated by using the above strategy and every node j is directly connected to j+{n-1} for all nodes j number between 0 and {n-1}/2.

Kamalesh and Srivatsa[10], presented a simple incremental technique, in which the nodes are indexed using symbols. Considering the cost of establishing the links between the nodes, a matrix is created and subsequently accumulated cost of each of the nodes is calculated. The accumulated cost column is sorted for increasing order. The nodes are numbered based on the increasing order of the accumulated cost. Nodes are connected by the link using the following steps.

For i=1 to k do the following

- establish link between node i and a where node b is a node which is not i
- if in the above step (i) generates any parallel links then such parallel links has to be removed.

This above 2 steps generates a required k-connected network.

Kamalesh and Srivatsa[11], in their article "on the design of survivable network" have proposed graph theoretical based method for the construction of k-node connected network topological structures. In this method the nodes are indexed based on the link cost and accumulated cost between all pair of nodes. Once the nodes are numbered keeping connectivity numberk in view, the node set is partitioned in to two sets X and Y.The required network is generated using the following

For i=1 to k,
For j= k+1 to n
Add a link between i and j
End of for
End of for

This method is mathematically modelled with the concept of a Bipartite graph.

Latha and Srivatsa[12] have modified the link deficit algorithm by determining minimum spanning tree of the given network in the first step and then applying Steiglitz link deficit algorithm. Further they demonstrated the above algorithm for setting up of 3- connected network.

Lee and Jung[13]proposed a method for constructing 2 vertex connectivity network topology for a rural terrestrial telecommunication network by using IEEE 801.11 component. Keeping in view of the cost, height, length of the links and other complicated issues like natural obstructions on the site.

3. Algorithmic Profile Analysis, Results and Discussions

The methods proposed by various authors are explored in detail. The computer programs are developed for the above proposed methods and the algorithmic profile are examined in detail. Based on the above results the merits and demerits of the above proposed strategies are discussed in detail below.

The link Deficit algorithm proposed[7] is a heuristic for generation of k-connected survivable network topological structures. It is one of the earliest heuristics which is widely used. The heuristics starts by randomly numbering the nodes. The randomization leads the algorithm for creating multiple network topologies with the same connectivity number for the given set of input data.

Further the heuristics demands recursive searching the nodes of the network during conflicts, as a result the algorithm is not computationally efficient.

The method proposed[8] is not a generic method. The algorithm is applicable only when the number of nodes are even in number and also the nodes are numbered arbitrarily. However the method is mathematically modelled. The design of cheapest survivable network proposed[9]have been claimed in their work as a generic method but they are nothing but harary graphs which was given by harary. [3]The design of harary graphs are depicted as a method, the harary graphs are circular graphs where the network topology looks like a regular polygon , also this method is not mathematically modelled.

The minimum spanning tree based method proposed[12] is however due to random numbering of nodes and repeated searching the nodes demands the more complicated time. Further this method is applicable only to generate 3-connected network**.**

In the above methodsgenerates the starting network topology structures. To get the required network the starting network has to be subjected for modification by using the standard technique which has branch exchange method cut saturation heuristics[1,2,14], connectivity restriction algorithm etc.

The incremental method proposed[10] is a simple and

Table 1. Comparative Analysis

	Steigltz et. Al	**S. Latha et .al Gray code**	**Latha et.al Polygonal Method**	**S.K srivatsa et.al Incremental method**	**S.K srivatsa et.al Bi partite method**	**S. Latha et .al Minimum spanning tree**	**Lee et.al Rural Terrestrial**
Mathematically Modelled	NO	YES	NO	YES	YES	YES	NO
Generic Method	YES	NO	YES	YES	NO	NO	NO
Node numbering techniques used	NO	NO	NO	YES	YES	NO	NO
Generates multiple topology for the same input	YES	YES	NO	NO	NO	YES	YES
Repeated searching of nodes	YES	YES	YES	NO	NO	YES	YES
Computation efforts	Very high	NA	Better compared to [1]	Better compared to [1]	Better compared to [1],[2],[3],[4]	NA	NA
Link optimality	NO	NA	YES	NO	YES	NA	NA
Remarks	General method but algorithm complexity is more compared to other methods.	Not a generic method, it is applicable if and only if number of nodes is 2k number.	Nodes are equispaced and generates circular topology only.	It is simple and straight forward method without any specific assumptions.	Method is applicable for all network with k<=n/2.	Generates only 3 connected networks.	Generates only 2 connected networks.

direct method. It is a most generic method which does not involve any of the pre consideration on the geographical position of the node. This method is widely used in the latest VPN telecommunication technology.

It is also preferred for the design of wireless sensor network, as the maximum hop is 2. As a result the transmission delay is minimized once.

This method incrementally generates all topologies starting from one to k- connected network. The major setback of the method is that it is not cost optimal and also not link optimal.

Further number of links in the first step of the algorithm is n – 1 and n-2 links in the steps continuing in the same way in the Kth step is n-k summarising above the total number of links added will be nk - $\sum_{k=0}^{n} K_{10}$

The methods proposed[11] is graph theoretically modelled based on bipartite graph theorem. The authors have claimed that the method is link optimal for all values of n and k where n is the total number of nodes and k is the required number of links. But however the method fails to address the drawback which is not explored in any current literature, is that the method works only for k<=(n/2). For all k>(n/2) the method fail to address however the maximum hop is only 2. Therefore the network topology has a minimum transmission delay and this is very much suits for a wireless VPN.

The detailed comparative analysis on existed developments is discussed in Table 1.

4. Conclusion

In the topological design of computer communication network structures, the most essential consideration is reliability of the network structures. The network systems are reliable if the underlined physical system is fault tolerant. This research work presents a detailed review of techniques strategies and current developments in the field of generations of fault tolerant network topological structures. It is clear from the above study that there is no method or technique which addresses most of the issues. Thisleads to scope for further research in the field.

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